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Location-Based Dynamic Route Guidance System of Korea: System Design, Algorithms and Initial Results

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Abstract

Over the last two years, the Korean Expressway Corporation (KEC) has developed a location-based dynamic route guidance system. The targets of the new system are the users of mobile-phones, the internet, and PDAs (Personal Digital Assistant), etc. Spatially the system covers 2,804 km of expressway and 484 km of national highway where the travel time collection systems are installed. The developed routing system is in many aspects different from the existing telematics-related services in Korea. It is based on predicted traffic information rather than real-time traffic information, and provides web and location based in-vehicle route guidance system. It utilizes GML (Geographical Markup Language) and GIS (Geographical Information System) in order to create GML DB (Data Base), and follows the standard format of the ISO (International Standard Organization) for GDF (Geographic Data File). Initial results of the proposed system including the accuracy of route travel time forecasts and the soundness of suggested routes were found to be acceptable. After development, the KEC has successfully tested a pilot service of the new system and is currently preparing for a full-scale implementation.

Keywords: *location based system, telematics, dynamic route guidance systems, geographical markup language*

1. Introduction

The Freeway Traffic Management Systems (FTMS) of the Korea Expressway Corporation (KEC) collects traffic information using loop and video image detectors on a 2804 kilometer stretch of the expressway. The collected spot speeds are converted into section travel time estimates and they are distributed to the users through a number of media devices including VMS (Variable Message Sign), mobile phones, radio & television, internet, and car navigation systems, etc.

The well-known car navigation service in Korea is 'MOZEN' of the Hyundai and Kia companies (e.g., http://www.mozen.com), and popular mobile phone-based traffic information services including 'NateDrive' of the SK telecommunication company (e.g., http://drive.nate.com) and 'K-ways' of the KTF company (e.g., http://www.k-ways.com). These systems provide navigation /routing, traffic, and safety-related services to its users. However, they are limited in that i) their routing logic is based on real-time (i.e., instantaneous) traffic information rather than the predicted traffic information and ii) they do not provide geo-spatial web services that follow the international standards.

Over the last two years, the KEC has developed a location-

Fig. 1. Network Coverage of the System: Expressway and Part of National Highways in Korea

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based dynamic route guidance system. The targets of the developed system are the users of mobile-phones, the internet, and PDAs (Personal Digital Assistant), etc. Spatially the system covers 2,804 km of expressways and 484 km of the national highways, as shown in Fig. 1, where the travel time collection systems are installed. Recently the KEC has been preparing a full-scale implementation of the system. This study provides an overview of the system design and algorithms and discusses the initial results of the proposed system.

This paper firstly discusses the unique features of the developed system. Secondly, the system architecture is outlined. Thirdly, the network representation using links and nodes are provided. Fourthly, the procedures for collecting travel time-related data, estimating and forecasting link travel times are introduced. Then path finding algorithms based on the predicted link travel times, including multiple path finding and resource-constrained path finding algorithms are provided. Lastly, initial results of the proposed systems are discussed followed by concluding remarks.

2. Literature Review

2.1 Route Guidance System

The Route Guidance System (RGS) is classified into two: Distributed and Centralized. The ALI_SCOUT system, which began field studies in Berlin in 1988, was a centralized RGS in which the best route was identified by a central computer and then sent to the vehicles (Hoffman and Janko, 1990). The distributed RGS includes CD-ATIS in New York State, ADVANCE in Chicago, Vehicle Information and Communication System (VICS) in Japan (Boyce, 2002; Yamashita *et al*., 2004; Demers *et al*., 2006). In these systems each equipped vehicle has an on-board computer which calculated the “best” route for the driver based on the travel times provided by the traffic information center. These systems mainly use historical and real-time travel time data to identify the best route and for some of them predicted travel time information is used. The developed system in this paper is different from the existing RGS in that it is purely predicted travel time-based and LBS-based one which identified multiple number alternative of paths.

Boyce (2002) reviewed the organization and experience of the Advanced Driver and Vehicle Advisory Navigation Concept (ADVANCE) project from the standpoint of public agencies and private organizations. He present variety results such as i) the background of the project and the apparent objectives of the participants, ii) the feasibility study of the project, iii) the negotiation of the Intelligent Vehicle Highway System (IVHS) agreement, and iv) several issues related to the experience and outcome of the partnership. Demers *et al*. (2006) described the Capital District Advanced Traveler Information System (CD-ATIS) and compared it to the ADVANCE project. The study area, design, and participant selection of the experiment were outlined as well. Shi *et al*. (2005) introduced an intelligent RGS based on agent-network, which can automatically guide vehicles by voice. They developed the system by applying the dynamic routing algorithm. Through the simulation study, the effectiveness of the proposed system was illustrated.

2.2 Travel Time Forecasting

With the development of the Advanced Travelers Information Systems (ATIS), short-term travel time prediction is becoming increasingly important (Chien and Chen, 2001a, 2001b). Various models have been developed that are able to predict link travel time, which is an important component in the RGS. Methodologies that have been commonly deployed for short-term travel time forecasting include Kalman Filter (Chu *et al*., 2005), time-series nonlinear models (Lshak and Al-Deek, 2002), time-varying coefficient (Rice and Zwet, 2001; Zhang and Rice, 2003), support vector regression(Lam and Toan, 2008), and neural network (Park and Rilett, 1998, 1999; Park *et al*., 1999). Many of the methods proposed for long-term forecasting concern the estimation of historical profile instead of short-term forecasting (Chien and Huchipud, 2003; Schrader *et al*., 2004; Kim *et al*. 2007).

3. Unique Features of the Developed System

Figs. 2 and 3 respectively show the conceptual framework of the web and location-based routing services, and the information flow of the developed system. The basic services of the system are as follows:

- Web and location-based routing and navigation services;
- Optimal path finding services considering future traffic conditions;
- Additional value-added services relevant to dynamic in-vehicle route guidance.

For these services, the new system was designed to identify the expected optimal route and to estimate its expected travel time for a given origin-destination pair when departing at the present time or at any future time period. It was also designed to periodically provide an in-vehicle dynamic routing service based on the current location of vehicles. For example, if an incident occurs, it automatically provides a revised optimal route for the

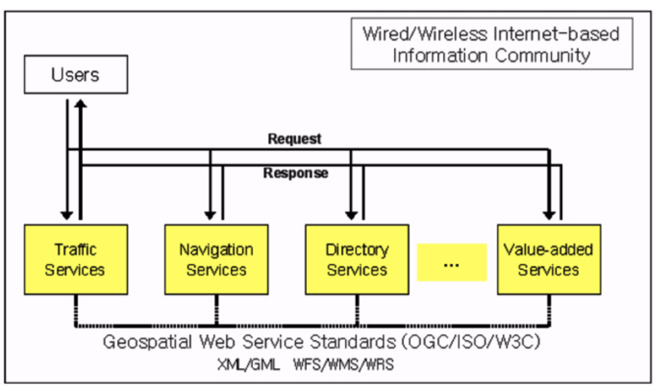

Fig. 2. Conceptual Framework of the Location-Based Routing Services

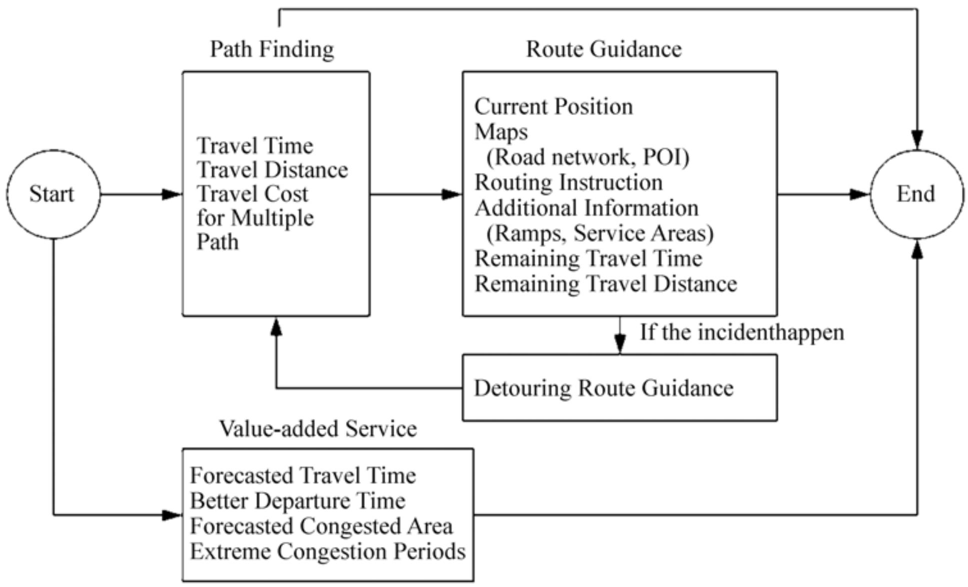

Fig. 3. Information Flow of the Developed System

driver, taking into consideration the new traffic conditions.

The developed routing system is in many aspects different from the existing telematics-related services in Korea. Firstly, it is based on predicted traffic information rather than real-time (or instantaneous) traffic information. Secondly, it provides a location-based in-vehicle route guidance system using mobile phones and PDAs that is quite different from the existing traffic information and telematics-related services. Thirdly, it provides multiple alternative paths rather than a single optimal path.

From a system point of view, the new system is considered as a state-of-the-art route guidance system in Korea. It applied GML (Geographical Markup Language) and GIS (Geographical Information System) in order to create GML DB (Data Base), which is essential for location–based geo-spatial web services. The standard format of the ISO (International Standard Organization) for GDF (Geographical Data File) was applied in this process. The WFS (Web Feature Service) and WMS (Web Map Service), which are the standard interfaces for the web GIS service, were also adopted.

4. System Architecture

The developed routing system consists of four parts: web-server, web application server, traffic data processing system, and web GIS server. Fig. 4 shows the relationships among these four parts. The traffic data processing part estimates and predicts

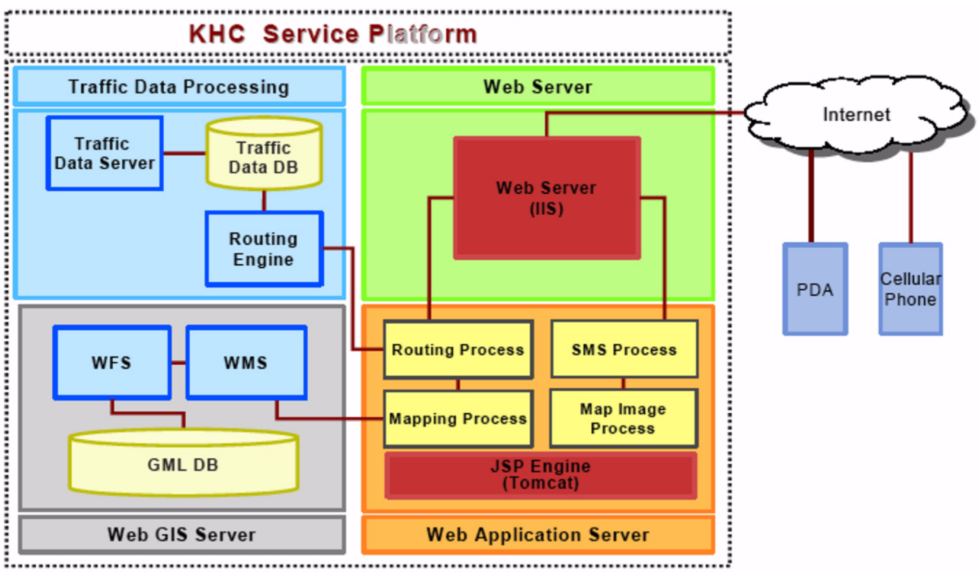

Fig. 4. System Architecture

travel time information and identifies the dynamic optimal routes. The other three components cover the telematics-related service processing. The detailed roles of the four components are discussed in this section.

4.1 Web Server

The web-server enables users to access services through the internet by mobile phones or PDAs. It passes the requests of users to web application servers, and transfers the corresponding services to users through the internet. If users request services through the internet using mobile phones and/or PDAs, it transfers the users' requests to the web application server and passes the corresponding results to the users. For this function, the project utilized Microsofts' IIS (Internet Information Server).

4.2 Web Application Server

The web application server, which processes the business logic of the developed system, consists of five components: routing process, SMS (Short Message Service) process, mapping process, map image process and the JSP (Java Server Page) engine. The routing process transfers routing-related information given by users such as origin, destination, and route-related conditions (e.g., maximum toll), to the routing engine of the traffic data processing component and receives the optimal route-related information from it. The mapping process displays the identified optimal path (i.e., drawing a map image) using the WMS of the web GIS server. The map image process modifies the size and resolution of the map image according to the users' terminal. Lastly, the SMS process provides routing-related information such as on/off ramps, service areas and incidents via text messages. For the web application server, this project employed Tomcat as a JSP engine.

4.3 Traffic Data Processing System

The traffic data processing system has three components: i) a traffic data server which preprocesses traffic data from the traffic information center, ii) a routing engine which identifies an optimal path under prevailing and predictive traffic condition, and iii) a Unix platform-based Oracle DB. The traffic data server estimates and predicts the link travel times using the loop data and passes them to the Oracle DB. The routing engine identifies the optimal route considering the routing-related information given by users such as origin, destination, and route-related conditions (e.g., maximum toll) and the link travel time forecasts. It then passes the results to the web application server.

4.4 Web GIS Server

The main function of the web GIS server is to display the identified optimal path on the map and provide it to the users. The web GIS server consists of three components: WFS, WMS, and GML DB. This project adopted the Cartalinea of the Galdos Company in Canada which follows the interface standard of WFS and WMS. The Cartalinea is based on the GML, which is an XML (Extensible Markup Language) for modeling, encoding, transmission and storage of all forms of geographical data. This project used GML and GIS in order to create GML DB, which is required for location–based geo-spatial web services. Fig. 5 shows the overall GML DB building procedure.

In the GML DB, the road network was presented by the GDF road network model. A level 1 network (simple features), describing the on/off ramps, links and link connectors, is used for navigation, and a level 2 network (complex features), describing the interchanges, toll gates and displaying links for travel information, is used for routing. Fig. 6 shows an image sample for the navigation service.

5. Network Representation

The expressway and national highways are divided into links using following rules:

- Designating as nodes, interchanges, junctions, changing point of the number of lanes, tunnels, service areas, etc;
- Shorter links with heavier traffic and higher level of congestion;
- Shorter links with shorter loop spacing.

Using the above rules, 1,721 links were defined, of which 973 represent basic expressway segments, and the others represent connectors of interchange, junction and service areas. The link lengths of the basic expressway segments range from 3.0 km near the metropolitan areas to 15.0 km in the rural areas.

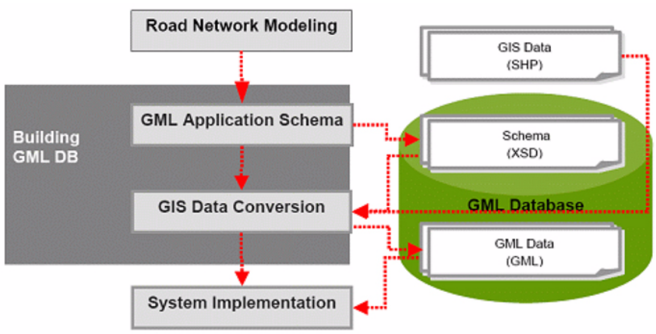

Fig. 5. GML DB Building Process

Image Sample for Exit Guidance Service

Image Sample for Routing Instruction in Navigation Service

Fig. 6. Navigation Image Sample

6. Traffic Data Processing

As shown in Fig. 7, after collecting the raw traffic data, link travel times (i.e., real-time profiles) are estimated. Then a historical profile representing the average observed link travel times over a certain number of past time periods (e.g., last 90 days) is constructed. Next the link travel times for the future time periods are predicted based on real-time profiles and historical profiles. Lastly, an optimal route for a given origin-destination pair is created and provided through mobile phones, PDAs, and other media. The details of each step are as follows:

6.1 Raw Traffic Data Collection

The KEC maintains 1,876 loop detectors for traffic data collection and Toll Collection Systems (TCS) for toll collection. Spot speed and traffic volume are obtained from the loop detectors and spatial traffic information such as space mean speed is collected from the TCS. Loop detectors have been installed on over the 90 percent of the expressways. In this project, a basic travel speed of 5-minute duration from each loop detector is used to estimate link travel times. However, if a loop detector is not available, travel time information from the TCS is utilized.

6.2 Link Travel Time Estimation (Real-time Profiling)

Link travel time for each time period (or each aggregation interval) is estimated by cell length (i.e., roadway segment between loop detectors) and the traffic volume weighted harmonic mean of the loop detectors speeds. For the expressway segments where general lanes and HOV lanes co-exist, a travel speed for each lane is estimated. The link travel times are estimated for every 10 minutes (i.e., an aggregation interval of 10 minutes) based on the results of the statistical models (See [KEC, 2005] for details). After estimating link travel times for each time interval, the simple exponential smoothing method is applied in order to remove noise or randomness.

6.3 Link Travel Time Forecasting under Non-Incident Condition

As shown in Fig. 8, link travel times are predicted every 10 minutes and future time periods are divided into 10 minutes intervals. The project uses Artificial Neural Networks (ANN) to forecast link travel times, which has been shown successful in previous studies Park and Rilett (1998, 1999), Park *et al*. (1999). After comparing different input sets, the best structure of ANN was found as follows;

Inputs: tt(h-7), tt(h-6), tt(h-5), tt(h-4), tt(h-3), tt(h-2) from the target and downstream links;
Outputs: tt(h), tt(h+1), tt(h+2), tt(h+3), tt(h+4), tt(h+5) of the target link

where tt(h) = travel time of time period h.

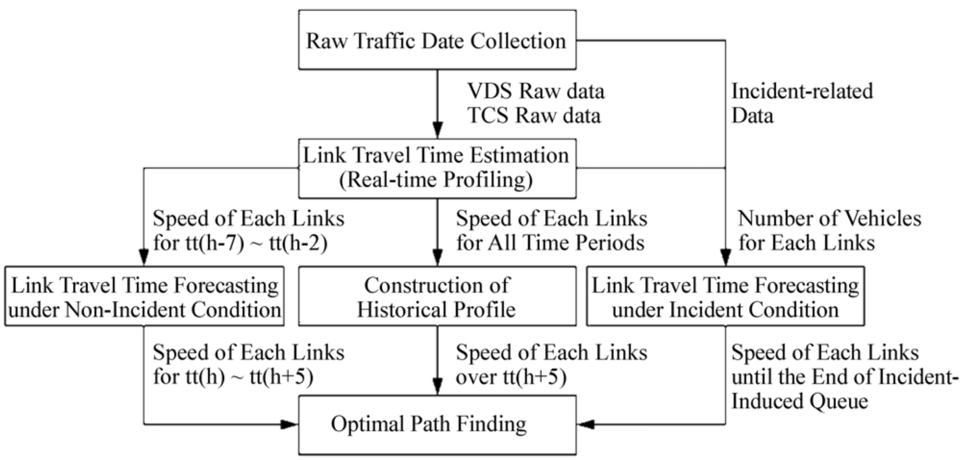

Fig. 7. Conceptual Diagram of Traffic Data Processing

Time interval	Link 1	2	3	4	....
h	$\hat{tt}_1(h)$	$\hat{tt}_2(h)$	$\hat{tt}_3(h)$	$\hat{tt}_4(h)$	....
h+ 1	$\hat{tt}_1(h+1)$	$\hat{tt}_2(h+1)$	$\hat{tt}_3(h+1)$	$\hat{tt}_4(h+1)$	....
h+ 2	$\hat{tt}_1(h+2)$	$\hat{tt}_2(h+2)$	$\hat{tt}_3(h+2)$	$\hat{tt}_4(h+2)$	....
⋮	⋮	⋮	⋮	⋮	⋮

Link travel time forecasts
At time period “h”

Update of link travel time forecast

Time interval	Link 1	2	3	4	....
h+ 1	$\hat{tt}_1(h+1)$	$\hat{tt}_2(h+1)$	$\hat{tt}_3(h+1)$	$\hat{tt}_4(h+1)$	....
h+ 2	$\hat{tt}_1(h+2)$	$\hat{tt}_2(h+2)$	$\hat{tt}_3(h+2)$	$\hat{tt}_4(h+2)$	....
h+ 3	$\hat{tt}_1(h+3)$	$\hat{tt}_2(h+3)$	$\hat{tt}_3(h+3)$	$\hat{tt}_4(h+3)$	....
⋮	⋮	⋮	⋮	⋮	⋮

Link travel time forecasts
At time period “h+1”

Fig. 8. Conceptual Framework of Link Travel Time Forecasting

Note that in a real forecasting environment, tt(h-1) representing link travel time from -10 minutes to 0 minute (i.e., current time of day) cannot be used as an input variable for ANN because it cannot be estimated at the time when ANN is applied.

Table 1 shows the results of selected links from the Kyeongbu expressway. Among 33 days of data from March to April in 2003, 20 days were used for training, 7 days for calibration and 6 days for validation. It may be seen that the mean absolute percentage errors from one time period ahead (i.e., tt(h)) to six time periods ahead (i.e., tt(h+5)) are less than 7.0%. It may be also seen that as the forecasting time period increases, the forecasting error also increases. Note that the forecasting errors from the historical profile are a little bit higher than those for the six time periods ahead. Given this result, the travel time forecasting for the time period of future 60 minutes is performed by the ANN models, while the travel time forecasting after 60 minutes from the current time of day is predicted by the historical profiles.

When applying the ANN models for travel time forecasting, the appropriate number of the ANN models should be decided, i.e., the spatial transferability should be checked. Table 2 presents the results of the spatial transferability of the ANN models for travel time forecasting. The spatial transferability is very low indicating that the ANN model should be developed for each link, as undertaken in this project.

Other important issues with respect to travel time forecasting are "how many days of data should be used for ANN calibration (i.e., optimal data size for calibration)" and at the same time "how open the ANN model should be calibrated (optimal calibration frequency)". To answer these two questions, this project tested nine scenarios: three cases on the "optimal data amount" for calibration (i.e., 30, 60, and 90 days) and another three cases on the "optimal calibration frequency" (i.e., 30, 60, and 90 days).

To test 9 different scenarios, 180 days of data collected from March to September in 2003 were used. Among the 9 scenarios, the 30-90 model was the worst and the 90-30 model was the best, although the results of the latter were not much better than those of the 30-30 and 60-30 models. Therefore, considering the calibration time and data storage, the 30-30 model was chosen, indicating that the ANN calibration for each link is done every month using the real-time profiles of the previous month.

6.4 Link Travel Time Forecasting under Incident Condition

One of the most important and challenging information areas for a successful dynamic route guidance system is reliable link travel time forecasts under incident conditions. Considering the number of weaknesses of the incident-related data collection system of the KEC, this project applied "shock-wave theory" for this purpose. The KEC detects incident based on the drivers' call

Table 1. Link Travel Time Forecasting Error from ANN (MAPE* (%))

Link	Historical Profile	ANN Model					
		tt(h)	tt(h+1)	tt(h+2)	tt(h+3)	tt(h+4)	tt(h+5)
Seocho-Yangjae	4.0	1.4	1.9	2.4	2.9	3.3	3.8
Yangjae-Dalraenae	2.7	1.8	2.6	3.4	4.1	4.7	5.2
Seoul TG-Chukjeon	8.2	2.2	3.0	3.9	4.7	5.5	6.4
Chukjeon-Shingal JC	4.1	1.8	2.6	3.3	4.1	4.9	5.7
Ohsan-Wongok JC	3.6	1.8	2.1	2.3	2.8	3.0	3.4
Wongok JC-Anseong	5.6	1.5	1.9	2.3	2.6	3.0	3.3
Namee-Chungwon	4.9	2.1	2.7	3.2	3.6	4.0	4.4
Chungwon-Chukam	5.4	2.0	2.7	3.2	3.8	4.2	4.5
Hwaeduk JC -Daejeon	3.6	1.7	2.2	2.6	3.0	3.3	3.6

* Mean absolute percentage error

Table 2. Results of Spatial Transferability of the ANN Model

Link used for ANN Calibration	Link used for Spatial Transferability Test	Forecasting Error from ANN (%)					
		tt(h)	tt(h+1)	tt(h+2)	tt(h+3)	tt(h+4)	tt(h+5)
Yangjae-Seocho	Yangjae-Seocho	1.4	1.9	2.4	2.9	3.3	3.8
	Dalraenae-Yangjae	6.4	10.0	14.0	18.0	21.6	24.5
	Chukjeon-Seoul TG	7.0	8.2	9.7	11.3	12.9	14.4
Wongok-Anseong	Wongok-Anseong	1.8	2.1	2.3	2.8	3.0	3.4
	Anseong-Wongok	3.4	3.6	3.8	3.8	4.1	4.3
	Chungwon-Namee	6.5	6.8	7.1	7.3	7.4	7.5

and/or patrol cars' observation. The inputs and outputs of the model are as follows:

Inputs: Incident location, occurrence time, number of lanes blocked, vehicle type, number of vehicles on upstream link, estimated incident duration, upstream traffic volume, capacity of incident location, etc;

Outputs: Link travel speed forecasts of each incident-related link for future time periods (from the beginning of the incident and to the end of incident-induced queue).

The incident duration is predicted by the cross-classification model calibrated using the incidents recorded in 2003 (about 7000 incidents). The detailed description is available in KEC (2005).

6.5 Construction of Historical Profile

When constructing a HP (Historical Profile), a number of questions must be answered. One of them is how many HPs should be constructed? That is, the necessity of weekly differentiation needs to be checked. In order to answer to this question, this study conducted a statistical test (comparing two means) using the link travel time data from 30 links (from Seoul to Daejeon) on the Kyeongbu expressway in Korea. The travel time data was collected from the Loop detectors from March to August in 2003 (yielding 180 days of data). The link travel times were aggregated into 10-minute intervals, which yielded 144 intervals for a day (6 interval/hour×24 hour).

It was found that each day of the week had different link travel times. Particularly when the portion of intervals, where link travel times on Sunday are equal to those of other days of the week were found to range from 1/3 to 1/2. In the case of comparison between Saturday and other days of the week, the portion of intervals where link travel times are the same, ranging from 1/2 to 2/3. Based on these findings, it was decided that the HP is constructed for each day of the week.

Other important issue with respect to the HP is "how many days of data should be used for HP construction (i.e., optimal past data size)" and at the same time "how open the HP should be calibrated (optimal calibration frequency)". Similar to the ANN models used for the link travel time forecasting, based on the statistical tests, HP was designed to be calibrated every month using the real-time profiles from the previous three months.

7. Path Finding Based on Link Travel Time Forecasts

7.1 Identifying Optimal Path and Estimating Expected Route Travel Time

In order to find an optimal path and estimate the expected travel time of the path, Eq. (1) was used.

$$E(l_j) = \min_{i \neq j}\{E(l_i) + E(c_{ij}(E(t_i)))\} \tag{1}$$

Where,

l_O = departure time at origin;

$E(l_j)$ = expected travel time from origin to node j;

$E(t_i)$ = expected arrival at node i (or departure time at node i);

$E(c_{ij}(t))$ = expected link travel time of link i, j when departing node i at time t.

Strictly speaking, the Bellman's Principle of Optimality does not hold in a dynamic and stochastic traffic network (Pattanamekar *et al*., 2003; Fu and Rilett, 1998). The conventional labeling approach based on the notion of Equation 1, thus, may produce erroneous results. However, this project relies on the logic of Eq. (1) for finding optimal path because the probability of identifying a non-optimal path as an optimal path is very low (see Pattanamekar *et al*. (2003) for details).

When identifying the optimal or alternative paths in an interrupted traffic flow such as national highways in Korea, U-turns and P-turns should be considered as shown in Fig. 9. However, the conventional node-based labeling approach violates Bellman's Principle of Optimality. In this context, this project applied a link-based labeling approach rather than a node-based one.

7.2 Identifying Multiple and Reasonable Alternative Routes

Drivers prefer to be provided with a multiple number of reasonable alternative paths rather than a single optimal path. For this, the project utilized the definition of "reasonable alternative paths" of Park *et al*. (2002) as follows:

> A path is a 'reasonable alternative path' if it not only has 'acceptable attribute value(s)' but is also 'dissimilar' in terms of the links used with respect to previously identified paths.

For this, this project employed the efficient vector labeling (EVL) algorithm (Park *et al*. 2002). Modified from the conventional label-setting based K-shortest path algorithm, the EVL algorithm deletes a sub-path which cannot satisfy the constraints in terms of overlapping between and/or among routes and attribute's constraint such as travel time and toll. It identifies multiple alternative paths which are acceptable in terms of attributes and do not overlap each other. The project assumed that each driver choose one of the path based on his/her preference.

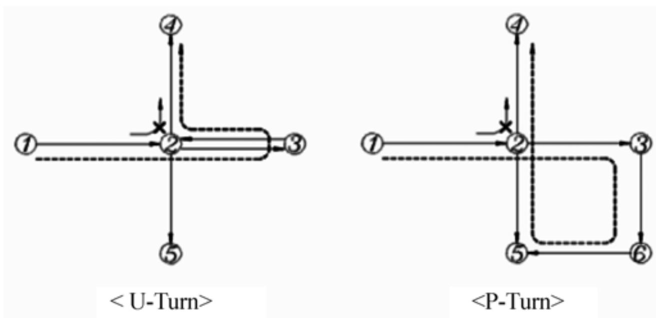

Fig. 9. Link-based Labeling Approach for U-turn and P-turn Movements.

8. Initial Results of the System

8.1 Experimental Study Design

To test the accuracy of the travel time forecasting processes and the reasonableness of the path finding algorithms, 182 origin-destination pairs were chosen from the whole expressway network in Korea. The average route distance was about 170 km. To test the impact of the level of congestion (i.e., time of day), seven different departure times (i.e., 07:00, 08:00, 09:00, 12:00, 16:00, 17:00, 18:00) were chosen. Accordingly, 2,548 (182 OD pairs×7 departure times) path searches were performed. Note that October 29 and 31were chosen for test dates and during the test time of days, 342 incidents were happened across the expressways.

8.2 Comparison between Predicted and Observed Route Travel Times

Table 3 shows the comparison results of the predicted and observed route travel times on 29 October 2004 (Friday) and 31 October 2004 (Sunday). For the former, the mean absolute error (MAE) and mean percentage error (MPE) were 3.3 minutes and 2.4%, respectively. The probability of MAE being less than or equal to 10 minutes was 92.9%, while the probability of MPE being less than or equal to 10 % was 97.0%. It was also found that afternoon departure times gave higher errors than morning departure times. The Sunday results were worse than the Friday results due to the weekend congestion. However, MAE and MPE on Sunday were within 10 minutes and 10%, respectively.

8.3 Other Results

The project tested the following three aspects to check the soundness of the path finding algorithms:

Probability that the suggested path is the same as the true optimal path;
Probability that the suggested path satisfies the constraint;
The portion of the path length overlapped with an alternative path.

For this, the EVL algorithm was used to identify two alternative paths. The maximum overlaps between them was set as 30%, whereas the maximum route travel time of the 2nd fastest path was set as 110% of the fastest path time.

Table 4 shows the results of October 29 and 31 in 2004. It may be seen that the probability of the suggested path being the true optimal path is about 90%. Similar to the previous section, afternoons and Sundays produced slightly worse results than mornings and weekdays. It is also observed that the EVL algorithm always satisfied constraints. The average overlaps between paths were about 40%.

9. Conclusions

This paper provided an overview of the location-based in-vehicle dynamic route guidance system developed by the Korea

Table 3. Predicted and Observed Route Travel Times

MOE	Date	Departure time							
		Avg.	07:00	08:00	09:00	12:00	16:00	17:00	18:00
Mean Absolute Error (MAE) (Min)	October 29, 2004 (Friday)	3.3	2.7	2.6	3.0	3.8	3.9	3.7	3.4
	October 31, 2004 (Sunday)	7.8	2.5	2.9	2.8	2.9	12.6	14.4	16.1
Mean Percentage Error (MPE) (%)	October 29, 2004 (Friday)	2.4	2.2	2.0	2.3	2.6	2.4	2.5	2.6
	October 31, 2004 (Sunday)	4.3	2.0	2.4	2.3	2.4	6.1	7.1	7.9
Probability that MAE is less than or equal to 10 minutes (%)	October 29, 2004 (Friday)	92.9	94.5	94.0	94.0	89.9	89.6	90.1	96.2
	October 31, 2004 (Sunday)	79.0	100.0	94.5	97.8	96.2	56.0	54.9	54.4
Probability that MPE is less than or equal to 10% (%)	October 29, 2004 (Friday)	97.0	96.7	96.7	95.6	95.6	97.8	98.4	97.8
	October 31, 2004 (Sunday)	85.0	98.4	96.2	97.3	97.8	73.6	69.8	64.8

* Average route travel time of all cases is 165.7 minutes

Table 4. Results of Other Tests

MOE	Date	Departure time							
		Avg.	07:00	08:00	09:00	12:00	16:00	17:00	18:00
Probability that the suggested path is the same with the true optimal path (%)	October 29, 2004 (Friday)	89.0	96.2	92.9	85.7	86.8	82.3	88.5	86.8
	October 31, 2004 (Sunday)	88.3	96.7	91.2	82.4	90.1	90.1	81.9	85.2
Probability that the suggested path satisfies constraint (%)	October 29, 2004 (Friday)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	October 31, 2004 (Sunday)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
The portion of path (length) overlapped with other alternative path (%)	October 29, 2004 (Friday)	40.8	40.4	40.2	39.9	39.3	41.1	42.7	41.9
	October 31, 2004 (Sunday)	41.3	40.8	40.3	40.2	41.3	42.1	42.0	42.3

Highway Corporation (KEC), which in many aspects is advantageous over the existing services currently provided in Korea. Initial results of the proposed systems including the accuracy of the route travel time forecasts and the soundness of the suggested routes seem acceptable. After developing the system, the KEC has successfully tested a pilot service of the developed system.

Currently the KEC is preparing for a full-scale implementation of the system. As part of the preparation, KEC is partnering with one of the biggest telecommunication companies in Korea. Sooner or later some telecommunication companies in Korea will commercially provide the developed service to the end users. In the meantime, KEC is planning to extend the network coverage of the developed system into the remaining parts of the national highways and urban arterials around the country.

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